ADF&G TECHNICAL DATA REPORT NO. 46
(Limited Distribution)

STATE OF ALASKA
Jay S. Hammond, Governor

1979 BRISTOL BAY SOCKEYE SALMON SMOLT STUDIES

Edited by:
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1980

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ADF&G TECHNICAL DATA REPORTS

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Data presented in these reports is intended to be final, however, some revisions may occasionally be necessary. Minor revision will be made via errata sheets. Major revisions will be made in the form of revised reports.

1979 BRISTOL BAY SOCKEYE SALMON SMOLT STUDIES

A summary of data collected from sockeye salmon (*Oncorhynchus nerka*) smolt programs in Bristol Bay, including Kvichak, Wood, and Snake Rivers

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ABSTRACT

Smolt projects were conducted on three Bristol Bay rivers in 1979. Estimates of outmigration sockeye salmon smolt were 52.6 million from Kvichak, 66.0 million from the Wood, and 1.3 million from the Snake River system. Age composition was 51% Age I and 49% Age II smolt from the Kvichak, 92% Age I and 8% Age II from the Wood, and 92% Age I and 8% Age II from the Snake River.

INTRODUCTION

This Technical Data Report represents a continuation in the documentation of sockeye salmon data collected from various Bristol Bay river systems. In 1979, smolt projects were conducted on three systems, Kvichak, Wood, and Snake. Sonar biomass counters were used to estimate smolt abundance on the Kvichak and Wood Rivers while a fyke net program was used on the Snake River. Length and weight data were collected from each age class of smolt on each of the three rivers sampled. Infection rate by _T. crassus_ was documented for smolt emigrating down the Wood River and climatological data are presented for each smolt site.

Smolt data is used to forecast returns of adults and to assist in establishing optimum escapement levels. These data are also used in assessing the effects of salmon rehabilitation and enhancement projects located in the Wood and Snake River systems.

1979 KVICHAK RIVER SOCKEYE SALMON SMOLT STUDIES

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INTRODUCTION

Data on age composition, size, and numbers of Kvichak River sockeye salmon (_Oncorhynchus nerka_) smolt migrating to sea are used in forecasting the age composition and numbers of subsequent adult returns to the Naknak/Kvichak fishery. Total smolt outmigration estimates from sonar enumeration began in 1971, replacing outmigration indices from fyke net catches (Russell 1972; Paulus and McCurdy 1972; Parker 1974a and 1974b). Collection of smolt age and size data as well as sonar enumeration of emigrating Kvichak River smolt continued in 1979.

METHODS AND MATERIALS

Installation and operation of the sonar counting system was similar to that of 1976 with the few changes noted below (Randall 1977). The system consisted of three 3.2 m plastic ladder assemblies, or arrays, each holding 14 sonar transducers. Each transducer had 100 m of electronic cable. The transducers were attached to the arrays and their cables gathered together into three separate bundles which were connected to a single control unit housed in a tent on the riverbank, where the entire system was monitored. Each array was independently anchored.

The sonar system functioned as a biomass counter and was designed to register one count for the biomass equivalent to 10 smolt passing over the sonar gear (Krasnowski 1975). The system was monitored 24 hours per day. Every 15 min counts were electronically totaled for each array and recorded on paper tape. Total counts were multiplied by 10 fish per count to estimate numbers of smolt passing over the three arrays.

Known false counts caused by wind, rain, snow, boats, etc. were subtracted from the counts printed on the paper tape. The normal procedure, however, was to disable the entire system when a known source of false counts appeared, e.g., boat, ice, etc. Counts during missed time were estimated by linear interpolation. The control unit printed out the number of seconds the system was disabled.

Each array sonified a section of the river approximately 3.7 m across. The counts from each array were expanded to estimate the number of smolt outmigrating in sections of the river not covered by the sonar gear. The width of the river at the sonar site changes with river discharge. In 1979 the river was 94 m wide with about 4 m on the west bank and 12 m on the east bank estimated not to be utilized by smolt. Figure 1 illustrates the position of the arrays in the remaining 78 m. The total daily counts were expanded to estimate the total daily outmigration based on the lateral distribution of sonar counts over the three sonar arrays. These expansion factors were 0.91, 1.02, and 1.05 for the western, center, and eastern sector, respectively.

The counting rate of the system was adjusted each season depending on river velocity. Water velocities were measured with a Gurley meter over each array mid season. Since the control unit was initially set for 5.40 fps, linear adjustments in the sonar counts had to be made for the differences in actual river velocity over all the arrays. Average velocities as measured on 2 May were 4.94, 5.50, and 5.68 fps over the inshore, center, and offshore array, respectively. A sample of a completed daily outmigration estimate with the adjustments for disable time, velocity differences, expansion for unsonified areas, etc. was presented by Randall (1977).

Samples from fyke net catches were used to determine mean lengths, weights, and age composition of the outmigrating smolt. A standard 1.2 x 1.2 m fyke net was fished in about 1.2 m of water in approximately the same location as the index site of previous years. Thirty smolt were collected for age, length, and weight data at 0600, 1200, 1800, and 2400 hour daily. Because the estimated age proportion was 60% Age II and 40% Age I, the smolt age samples were pooled into sample sizes of 200 fish or more which allowed detection of a 7% change in the age composition at the 95% confidence limit (Snedecor and Cochran 1967). As a result there were four sample periods between 3 to 10 days each. Estimated

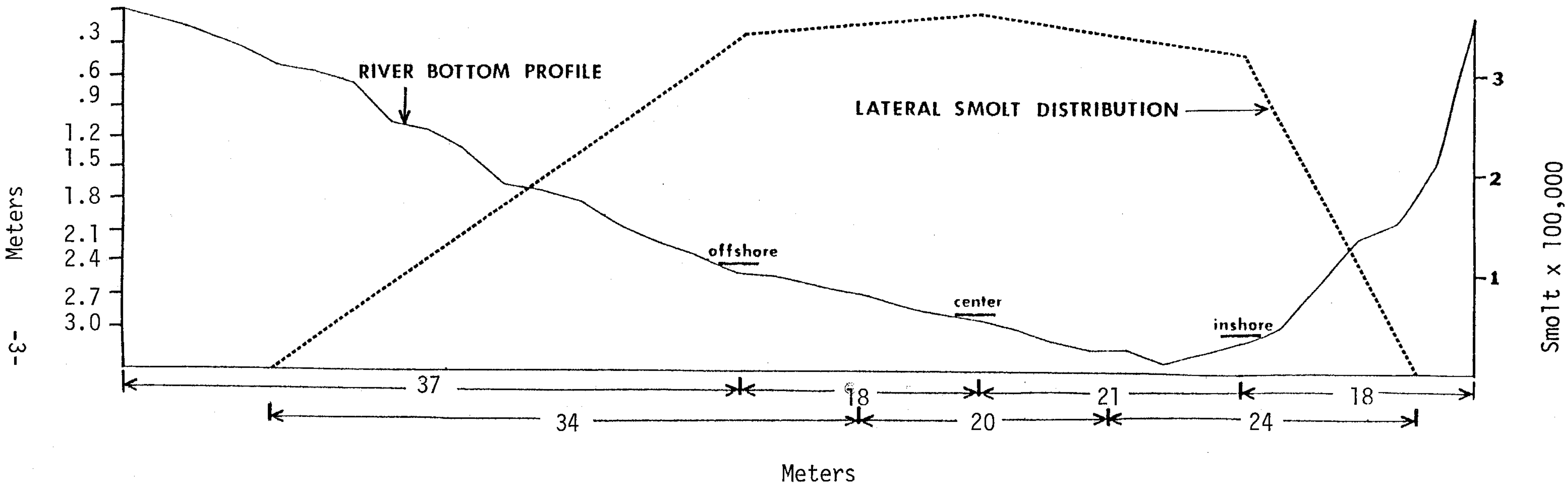

Figure 1. River bottom profile at sonar site, location of arrays, and estimated lateral smolt distribution Kvichak River, 1979.

age composition of the total outmigration was weighted by the outmigration estimate of each of the four sample periods. Length and weight data were not pooled because of significant differences between samples as few as one day apart. Estimated mean length and weight for the entire outmigration was obtained by summing the daily mean lengths and weights, each weighted by the corresponding daily outmigration estimate.

RESULTS

Climatological and Hydrological Observations

Weather and river conditions were recorded at the sonar site from 17 May through 11 June (Table 1). Air and water temperatures were recorded only in June and the warmest air temperature was recorded on 8 June. The average air and water temperatures during the 10-day sampling period were 11.2 and 8.6° C, respectively. There was ice above, but none at the sonar site in 1979. Water levels were higher than in 1978.

Outmigration Estimate

Over 1 million smolt had been counted when the study ended on 10 June (Table 2). This number gave an expanded count of over 52.6 million smolt (Table 3). The peak of the outmigration occurred between 25 and 26 May. The majority of the smolt counted during the project, i.e., 26.6 million, were Age I smolt from the 1977 escapement of 1.3 million spawners (Table 4). The remaining 26.0 million Age II smolt were the progeny of 2.0 million adults spawning in 1976. The 26.0 million Age II smolt added to 31.3 million Age I smolt that emigrated last year equal a total smolt production rate of 27 per spawner from the 1976 brood year (Table 4).

Age-Weight-Length

A total of 896 smolt were measured to determine mean weight, length, and age. Daily mean weights and lengths are presented in Table 5. The estimated age composition of the total outmigration was 50.60% Age I and 49.40% Age II smolt.

Mean weights were 6.0 g for Age I smolt (20 yr mean = 6.0 g) and 10.3 g for Age II smolt (20 yr mean = 11.1 g). Mean lengths were 89.6 mm for Age I smolt (23 yr mean = 88.7 mm) and 108.9 mm for Age II smolt (22 yr mean = 109.8 mm). The 1979 smolt were smaller than those produced from other peak -1 year cycles. Table 6 provides smolt age composition, weight, and length data for the years 1955 through 1979.

Table 1. Climatological and stream observations, Kvichak River, 17 May to 11 June 1979.

DATE	SKY 0800	SKY 2000	WIND (MPH) DIRECTION 0800	WIND (MPH) DIRECTION 2000	AIR TEMP CENTIGRADE MIN.	AIR TEMP CENTIGRADE MAX	WATER TEMP CENTIGRADE	PRECIP (INCHES)	WATER LEVEL [1/] FEET	TURBIDITY
May 17	3	3	15NE	10NE				0	9.90	2
18		3	5NE	Calm				0	10.08	1
19		3	5S	5S				A	10.19	1
20	4		5NE					0	10.24	1
21	2		10NE					0	10.28	2
22	2	4		Calm				0	10.12	1
23	4	2	5NE	5E				0	10.20	1
24	2	2	Calm	Calm				0	10.06	1
25	3	1	5NE	Calm				0	9.98	1
26	1		Calm	Calm				0	9.85	1
27	1	1	Calm	Calm				0	9.91	1
28	1	1	5NE	Calm				0	9.98	1
29	1	4	15NE	15NE				B	10.12	1
30		3		Calm				0	10.08	1
31	4		5NE					0	10.09	2
June 1	3	2	15NE	25NE			8	A	10.15	2
2	3	2	10NE	10NE	7	14	8.5	0	10.12	2
3	3	3	15NE	10NE	3	12	8	0	10.14	2
4	3	3	5NE	5NE	9	15	7.5	0	10.23	2
5	3	3	Calm	5S	5	20	8.5	0	10.16	2
6	4	3	5E	Calm	6	22	9.0	0	10.22	2
7	3	4	5NE	10NE	5	16	9.5	A	10.22	2
8		2		Calm	5	18	10.0	0	10.23	2
9	1	4	10SW	10SW	5	20		A	10.14	2
10	4	4	5SW	25SW	8	12		A	10.20	2
11	4		10SW					A	9.20	2

1/ depth of inshore half of center array

sky code:
1. cloud cover less than 1/10 of sky
2. cloud cover less than 1/2 of sky
3. cloud cover more than 1/2 of sky
4. completely overcast

precipitation code:
0. none
A. intermittent rain
B. continuous rain

turbidity code:
1. clear
2. light brown

Table 2. Kvichak River sockeye salmon smolt counts by array, less false counts, plus interpolation for missed time, 1979.

Date	Inshore	Center	Offshore	Total
May 16 1/	1,075	1,519	1,492	4,086
17	6,131	7,964	9,416	23,511
18	975	802	1,656	3,433
19	3,683	7,045	8,815	19,543
20	416	757	2,417	3,590
21	5,644	3,605	59,774	69,023
22	19,255	22,280	23,443	69,978
23	4,405	8,720	6,107	19,232
24	48,927	45,132	41,749	135,808
25	60,668	71,188	21,449	153,305
26	72,298	76,506	1,496	150,300
27	13,656	18,088	17,900	49,644
28	20,620	20,086	31,828	72,534
29	1,912	1,757	8,651	12,320
30	13,281	15,054	34,866	63,201
31	11,389	12,634	11,989	36,012
June 1	6,023	6,988	9,174	22,185
2	366	1,091	2,319	3,776
3	2,391	1,124	5,134	8,649
4	6,886	7,585	7,261	21,732
5	6,983	9,030	4,549	20,472
6	3,965	3,175	4,671	11,811
7	2,066	1,711	7,324	11,101
8	1,929	4,290	3,661	9,880
9	718	935	1,124	2,777
10	2,794	3,292	4,816	10,902
TOTAL	318,366	352,358	338,081	1,008,805
Percent of Total	.316	.349	.335	100

1/ 12 hours only, from 0001 to 1200 17 May.

Table 3. Daily smolt outmigration estimate, by age class with percent age composition, and accumulated totals, Kvichak River, 1979.

DATE	AGE I	%	ACCUM	AGE II	%	ACCUM	TOTAL	ACCUM
16 May	62320	0.29	62320	151913	0.71	151913	214234	214234
17	360336	0.29	422656	878358	0.71	1030271	1238695	1452929
18	53054	0.29	475710	129325	0.71	1159596	182380	1635309
19	303655	0.29	779365	740194	0.71	1899790	1043850	2679159
20	57771	0.29	837136	140824	0.71	2040614	198596	2877755
21	1140890	0.29	1978026	2781042	0.71	4821656	3921933	6799688
22	1071794	0.29	3049820	2612614	0.71	7434270	3684409	10484097
23	292504	0.29	3342324	713012	0.71	8147282	1005517	11489614
24	2035529	0.29	5377853	4961820	0.71	13109102	6997350	18486964
25	4282538	0.56	9660391	3411566	0.44	16520668	7694105	26181069
26	4203426	0.56	13863817	3348543	0.44	19869211	7551970	33733039
27	1446156	0.56	15309973	1152040	0.44	21021251	2598197	36331236
28	2132668	0.56	17442641	1698931	0.44	22720182	3831599	40162835
29	533899	0.78	17976540	147529	0.22	22867711	681429	40844264
30	2673432	0.78	20649972	738733	0.22	23606444	3412166	44256430
31	1465234	0.78	22115206	404879	0.22	24011323	1870114	46126544
1 June	812379	0.69	22927585	357185	0.31	24368508	1169565	47296109
2	144288	0.69	23071873	63440	0.31	24431948	207729	47503838
3	323977	0.69	23395850	142445	0.31	24574393	466423	47970261
4	783965	0.69	24179815	344692	0.31	24919085	1128658	49098919
5	726111	0.69	24905926	319255	0.31	25238340	1045367	50144286
6	428713	0.69	25334639	188495	0.31	25426835	617209	50761495
7	422988	0.69	25757627	185978	0.31	25612813	608967	51370462
8	362518	0.69	26120145	159391	0.31	25772204	521910	51892372
9	101704	0.69	26221849	44717	0.31	25816921	146422	52038794
10	401287	0.69	26623136	176436	0.31	25993357	577724	52616518

Table 4. Kvichak River sockeye salmon escapement, outmigration index or total estimate, age composition, and index or total estimate per spawner (estimated Age I smolt production between 1956 to 1968 and between 1969 to 1977 from indices and total outmigration estimates, respectively; estimated Age II smolt production between 1956 to 1970 and 1971 to 1977 from indices and total outmigration estimates, respectively).

BROOD YEAR	ESCAPEMENT	ESTIMATED SMOLT PRODUCTION AGE I	AGE II	AGE III	TOTAL	AGE PROPORTION AGE I	AGE II	AGE III	SMOLT PER SPAWNER
1956	9443318	3267274	2777960	0	6045234	0.54	0.46	0.	0.640
1957	2842810	85916	552603	0	638519	0.13	0.87	0.	0.225
1958	534785	61400	10126	0	71526	0.86	0.14	0.	0.134
1959	680000	26038	72180	0	98218	0.27	0.73	0.	0.144
1960	14630000	1130820	4116093	0	5246913	0.22	0.78	0.	0.359
1961	3705849	113338	1603464	0	1716802	0.07	0.93	0.	0.463
1962	2580884	458122	1748178	0	2206300	0.21	0.79	0.	0.855
1963	338760	64377	23377	0	87754	0.73	0.27	0.	0.259
1964	957120	252384	222528	0	474912	0.53	0.47	0.	0.496
1965	24325926	2866214	5475362	0	8341576	0.34	0.66	0.	0.343
1966	3775184	648321	541017	0	1189338	0.55	0.45	0.	0.315
1967	3216208	594327	298282	0	892609	0.67	0.33	0.	0.278
1968	2557440	185356	5959383	0					
1969	8394204	85723430	67004325	0	152727755	0.56	0.44	0.	18.194
1970	13935306	570750	189138158	4925610	194634518	0.00	0.97	0.03	13.967
1971	2387392	4987961	33767464	0	38755425	0.13	0.87	0.	16.233
1972	1009962	4021849	5784036	0	9805885	0.41	0.59	0.	9.709
1973	226554	9848495	2927804	0	12776299	0.77	0.23	0.	56.394
1974	4433844	99890123	132920297	0	232810420	0.43	0.57	0.	52.508
1975	13140450	82097299	243208705	0	325306004	0.25	0.75	0.	24.756
1976	1965282	26633417	25993357		52626774	0.51	0.49		26.778
1977	1341144	26623136			22419710				16.717

Table 5. Sample size, mean length (mm), mean weight(g) and variance for sockeye salmon smolt by age class and sample date, Kvichak River, 1979.

	Age I					Age II				
Date	Mean Ln.	Variance	Mean Wt.	Variance	N	Mean Ln.	Variance	Mean Wt.	Variance	N
May 18	84.50	31.38			10	109.74	40.93			23
19	91.67	7.25			9	110.00	39.41			28
21	94.14	13.83			7	111.17	20.88			23
22	93.11	13.61			9	108.65	16.00			26
23	88.31	44.50			16	112.46	25.06			26
24	89.68	9.29	5.96	0.29	1/	112.14	24.28	10.13	0.68	2/
25	88.95	16.42	6.01	0.57	65	109.15	18.56	10.46	1.06	20
26	89.68	13.78	5.83	1.55	28	111.72	15.75	11.04	1.72	32
27	93.00	0.67	6.65	0.10	4	112.65	19.92	11.84	2.11	26
28	89.85	15.00	6.41	0.98	47	105.85	20.97	9.92	1.42	13
29	89.19	16.41	5.92	1.11	72	107.77	15.96	10.12	2.09	13
30	86.97	23.38	5.84	1.06	35	107.75	8.25	10.35	0.25	4
31	88.54	13.44	5.84	0.68	82	110.25	26.50	10.45	2.74	8
June 1	90.17	21.86	5.89	0.89	24	110.27	18.22	10.15	3.13	11
2	90.50	15.62	6.60	0.64	26	106.75	20.92	9.97	1.18	4
5	85.52	24.44	5.23	0.84	23					
6	87.75	34.20	6.48	1.15	20	108.60	10.54	10.67	1.39	15
7	87.40	18.00	5.76	0.73	42	107.31	14.90	9.83	1.49	16
8	89.83	8.32	6.25	0.59	24	106.67	57.47	10.07	3.25	6

1/ 31 length samples 25 weight samples

2/ 28 length samples 4 weight samples

Table 6. Comparative age composition, length, weight, and outmigration estimate sockeye salmon smolt, Kvichak River, 1955-1979.

YEAR OF SEAWARD MIGRATION	AGE I %	AGE I LENGTH (mm)	AGE I WT (g)	AGE II %	AGE II LENGTH (mm)	AGE II WT (g)	AGE III %	AGE III LENGTH (mm)	AGE III WT (g)	OUT MIGRATION ESTIMATE 1/
1955	0.07	89.0		0.93						260068
1956	0.39	92.0		0.61	116.0					77660
1957	0.72	96.0	7.3	0.28	120.0	14.4				30907
1958	0.98	84.0	4.6	0.02	114.0					3333953
1959	0.03	80.0		0.97	99.0	7.6				2863876
1960	0.10	91.0	6.3	0.90	108.0	10.3				614003
1961	0.72	92.0	6.8	0.28	117.0	13.1				36164
1962	0.94	82.0	4.3	0.06	110.0	9.9				1203000
1963	0.03	83.0	4.8	0.97	98.0	7.5				4229431
1964	0.22	87.0	5.2	0.78	108.0	9.8				2061586
1965	0.04	90.0	6.8	0.96	109.0	11.3				1812555
1966	0.92	94.0	7.4	0.08	114.0	12.6				275761
1967	0.93	86.0	5.9	0.07	118.0	14.2				3088742
1968	0.11	88.0	5.5	0.89	104.0	9.2				6123683
1969	0.52	92.5	5.7	0.48	109.3	10.6				1135344
1970	0.38	90.8	6.0	0.62	110.2	11.0				483638
1971	0.94	89.9	5.8	0.07	111.0	11.1				91682813
1972	0.01	80.0	4.2	0.99	106.0	10.0				67575075
1973	0.03	85.6	5.1	0.97	97.1	8.3				194126120
1974	0.09	95.5	8.3	0.79	111.0	13.1	0.12	123.5	17.5	42714923
1975	0.63	97.7	8.4	0.37	121.9	16.4				15632531
1976	0.97	88.2	5.8	0.03	120.8	14.2				102817927
1977	0.38	86.0	5.5	0.62	106.0	10.1				215017596
1978	0.10	88.1	6.0	0.90	96.9	7.8				269842124
1979	0.50	89.6	6.0	0.50	108.9	10.3				52616518

1/ Fyke net indices from 1955 to 1970, sonar total outmigration estimates from 1971 to 1979.

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1979 WOOD RIVER SOCKEYE SALMON SMOLT STUDIES

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INTRODUCTION

The Wood River Smolt Project was initiated in 1951 to obtain an abundance index of the annual sockeye salmon smolt outmigration. Various programs designed to determine this index were operated until 1971 (excepting 1968). The index program was discontinued after the 1970 season because the relationship between this abundance index and the eventual adult return was extremely variable and of little value in forecasting the magnitude of future runs.

A more accurate and precise smolt outmigration estimate was needed for forecasting adult returns and estimating optimum escapement in the Wood River Lakes. Therefore, sonar smolt enumeration equipment was purchased, and a program was initiated in 1975 to estimate total smolt outmigration. This project has been continued through 1979 with the same objectives of estimating number, size, and age composition of the smolt emigrating from the Wood River system.

Smolt outmigration estimates for 1975 and 1976 originally published by Krasnowski (1977) were expanded for the entire width of the river and for a time the equipment was not operated, but were not multiplied by a sonar calibration factor of five smolt per count. Newcome (1978) published the 1977 results as "expanded sonar counts" and redefined the 1975 and 1976 counts as "expanded sonar counts." Clark and Robertson (in press), using the calibration factor of five smolt per count, published actual smolt outmigration estimates from "expanded sonar counts" for all years that sonar equipment has been used.

This report is a summary of the 1979 smolt program which incorporated new techniques for estimating the actual smolt outmigration. Recommendations are also given for simplifying the adjustment of sonar counts to yield more precise smolt counts.

METHODS AND MATERIALS

Sonar Arrays

The four transducer arrays and electronic control units used in 1979 were the same ones used from 1976-1978 (Krasnowski 1976, 1977; Newcome 1978). An attempt was made to place the arrays in the same locations as in 1976. The actual distances from the north bank of Arrays I, II, III, and IV were: 20.7, 34.4, 54.5, and 74.4 m, respectively. This put Array IV a distance of 43.9 m from the south bank, and 4 m farther south than its position in 1978. Even so, coverage of the southern portion of the river channel was minimal due to high water during the early part of the season. After the distances between the shoreline and the individual arrays were measured, expansion factors were calculated for those sections of the river channel that were not monitored by sonar.

With a few minor changes, the sampling design and sonar data collection procedures were the same as described by Krasnowski (1977). The arrays were installed in the river on 29 May and the counter was operated during index hours (2100-0300) that night. The daily random counting schedule was started on 30 May and continued until 2 August. The sonar gear was operated 75 hours (25 randomly selected 3 h blocks) per five-day sample period. Array I was used as the index array until 24 June, and was operated during all sampling hours. Arrays II, III, and IV were operated in a random sequence for 15-min intervals within each hour, and these 15-min counts were expanded to yield hourly counts for each array.

On 24 June the index array was changed from Array I to III after preliminary data analysis indicated more smolt were passing over Array III than Array I. The switch was accomplished by merely interchanging the transducer cables at the electronic switching unit from I to III.

River velocity was measured at least once per day with a pygmy Gurley meter. These measurements were made behind the index array (Array I until 24 June). Periodically, velocity measurements were taken behind the other three arrays. Lake depths were recorded daily at the Alaska Department of Fish and Game cabin at Lake Aleknagik for comparisons with previous year's data. During periods of sonar sampling, river depth at the sonar site was recorded every 15 min with the sonar counter. Daily air and water temperatures were also recorded at the sonar site.

Sonar Sampling - Adjustment and Expansion of Counts

The sonar counter was operated at one velocity setting (4.5 fps) all season. Because the river velocity drastically changed during periods of tidal influence, a velocity factor was applied to the raw counts to yield corrected counts.

Velocity models used in 1976 to estimate hourly velocity factors for adjusting the sonar counts (Krasnowski 1977) could not be applied to the 1978 velocity data. Therefore a method was developed, whereby the sonar counts were adjusted, corrected, and expanded in season (Appendix 1). A standard velocity factor (SVF) was used during periods of no tidal influence, while various tidal velocity factors (TVF) were used for those hours when high tides slowed the river current.

The SVF was derived at the end of each five-day sample period from daily velocity measurements taken behind the index array during non-tide influenced hours. The mean of these velocity measurements was then divided by 4.5 to produce the SVF for that period.

The TVF was derived from an accumulation of velocity measurements taken during the tide influenced hours. Krasnowski (1977) reported that the period of influence lasted 2 hours, from 1 hour after "book" high tide to 3 hours after high tide, with a peak at 2 hours after high tide. Measurements in 1979, however, indicated that the actual period of influence greatly varied throughout the season, being dependent upon the height of the tide and the water level of the river. Some of the samller high tides produced no effect on river velocity, while larger high tides sometimes influenced river velocities for as long as 6 h.

The procedure for calculating tidal factors was to monitor river velocity during both larger high and smaller high tides on or near the middle of the five-day period. Measurements from the Gurley meter anchored behind the index array were recorded every 15 min over a 2 to 4 h period. The length of time spent monitoring the Gurley meter invariably was less than the entire period of influence. Missing data at the end of this period were then graphically estimated by curve fitting and extrapolating (Appendix 2). The resulting factors, defined as F_1 and F_2, were derived from the graph in a fairly simple manner. If the period of tidal influence was only 2 h, F_1 was used to correct the first hour of influence while F_2 was used for the second hour. If the period of tidal influence was longer than 2 h, various averages of the two factors were used to adjust the counts.

Because river velocities were different over each array at any given time, an array ratio factor (ARF) was also used. Once per period, usually on or near the third sample day, velocity measurements were taken behind each array. These measurements were used to calculate the ARF, the ratio of river velocities behind the non-index arrays to those behind the index array.

After the raw counts were multiplied by the appropriate velocity factors to produce corrected counts by array, the corrected counts were expanded for the entire width of the river. An expansion factor was assigned to each array which remained constant throughout the season. These factors were a function of distance between the individual arrays with respect to the total distance across the river, less that portion of the southern channel not used by the smolt (Appendix 3). The expansion factors were as follows: Array I - 4.88, Array II - 4.50, Array III - 4.96, and Array IV - 5.75.

Because sampling was not done 24 hours per day, missing counts were interpolated for those time periods not sampled. After interpolation for missing data, counts were summed to yield a daily total expanded count. The electronic counter was designed to register one count for the biomass equivalent to five smolt. [Fyke net catches were compared with sonar counts to calibrate the sonar counter. Results were not comparable because heavy debris in the river caused the sonar gear to register a large but unknown percentage of false counts. Calibration tests made in 1978 (Clark and Robertson, in press) indicated that the sonar unit was counting as designed. It was assumed that the sonar counter was still counting at the proper rate of five smolt per count]. Therefore, the daily total expanded count was multiplied by five to estimate the actual daily smolt count.

Age-Weight-Length

Smolt were collected for age-weight-length analysis during each five-day sampling period. The samples were collected with a beach seine near the outlet of Lake Aleknagik. During late July adequate samples could not be obtained using the beach seine. A fyke net was thereafter fished directly behind Array I to obtain the samples. Fork length and scale samples were taken from each smolt. Weights were taken from at least 10 smolt per day (17% of daily sample) and all smolt were externally examined for presence of the parasite *Triaenophorus crassus*.

SCUBA Diving - Underwater Inspection and Adjustment

A series of high tides in mid-July, causing severe current reversals in the river, dislodged the arrays and moved them from their original positions on the river bottom. Anchors attached to the transducer cable bundles were also pulled loose, causing the cable bundles to be swept downstream and become tangled. Without anchors securing the cables, great strain was placed on the cables, breaking two of the safety lines. On 13 July, during one of the tide reversals, SCUBA gear was used to inspect the sonar gear and make necessary repairs. This proved to be a very effective means of repairing, cleaning, and adjusting the underwater equipment.

RESULTS

Climatological and Hydrological Observations

Daily water and air temperatures recorded at the sonar site during the smolt outmigration are presented in Table 1. Maximum and minimum seasonal water temperatures were 16° C (20 July and 2 August) and 4.5° C (as late as 6 June), respectively. The maximum and minimum air temperatures were 33° C (12, 16-18 July) and 1.5° C (27 June). A comparison of average lake and river depth measurements for the years 1975-1979 is presented in Table 2.

Outmigration Estimate

The sonar counter was operated for 13 five-day periods for a total of 65 consecutive days. A total of 1,664,325 raw counts were enumerated. Of this total, 17.0% were recorded by Array I, 27.1% by Array II, 33.1% by Array III, and 22.8% by Array IV. Daily outmigration estimates totaled 65,966,050 (Figure 1, Table 3). Table 3 also lists the estimated smolt outmigration by age class and sample period.

Age-Weight-Length

Age composition estimates and mean lengths by sample period derived from beach seine and fyke net sampling are given in Table 4. Weighted mean lengths for the season of Age I and Age II smolt were 89.7 mm and 99.8 mm, respectively. Age I smolt comprised 92.2% of the outmigration; Age II smolt comprised 7.8%, the majority of which emigrated during May and June. No Age III smolt were observed in the sample. A comparison of the mean length of smolt by year and age class for the years 1951-1979 is presented in Table 5. Mean weights by sample period are presented in Table 6. No seasonal mean weight is given since much growth occurred during the actual period of outmigration. Table 7 lists the estimated percentage of sockeye salmon smolt infected by the cestode *Triaenophorus crassus*. Overall, 10.0% of the Age I smolt and 30.8% of the Age II smolt were estimated to be infected by the parasite.

Table 1. Water and air temperatures recorded at Wood River sonar site, 1979.

Date	Water Temp. (°C)	Air Temp. (°C) Max.	Air Temp. (°C) Min.	Date	Water Temp. (°C)	Air Temp. (°C) Max.	Air Temp. (°C) Min.
5/30	4.8	19.0	7.0	7/ 4	10.0	26.0	10.0
5/31	4.5	17.0	8.5	7/ 5	11.0	16.0	12.0
6/ 1	4.8	21.5	9.0	7/ 6	11.0	21.0	12.5
6/ 2	5.0	21.0	7.5	7/ 7	11.0	28.5	17.0
6/ 3	4.5	18.0	7.0	7/ 8	10.0	29.0	17.0
6/ 4	5.0	22.5	8.0	7/ 9	11.0	23.5	13.5
6/ 5	4.5	26.0	9.5	7/10	11.0	27.0	16.0
6/ 6	4.5	21.5	7.5	7/11	12.0	32.0	16.0
6/ 7	4.8	17.0	6.5	7/12	13.0	33.0	10.5
6/ 8	5.0	23.0	6.5	7/13	11.0	23.0	10.5
6/ 9	5.0	25.0	9.0	7/14	12.0	26.0	12.0
6/10	5.5	19.0	8.0	7/15	12.0	29.0	12.0
6/11	6.3	20.5	6.0	7/16	10.4	33.0	9.0
6/12	6.8	11.0	3.0	7/17	14.0	33.0	12.0
6/13	6.5	22.0	8.5	7/18	15.0	33.0	8.0
6/14	7.0	20.5	7.5	7/19	-	-	-
6/15	6.8	14.0	3.0	7/20	16.0	29.0	7.0
6/16	6.5	13.0	6.5	7/21	12.5	20.5	11.0
6/17	6.3	14.0	7.0	7/22	9.0	14.5	11.5
6/18	6.3	12.5	8.0	7/23	8.0	14.5	11.5
6/19	6.8	13.0	7.0	7/24	9.0	20.0	5.0
6/20	6.3	25.0	3.0	7/25	11.5	25.0	5.0
6/21	7.3	27.5	3.5	7/26	12.5	20.0	4.5
6/22	6.8	27.0	2.5	7/27	13.5	27.0	10.0
6/23	7.0	24.5	5.0	7/28	15.0	22.5	10.0
6/24	6.5	17.5	7.5	7/29	14.0	19.0	13.0
6/25	6.5	12.5	7.0	7/30	15.0	31.0	12.0
6/26	7.5	21.0	7.0	7/30	15.0	27.0	11.0
6/27	8.2	23.0	1.5	8/ 1	15.0	25.0	7.0
6/28	8.2	21.0	3.5	8/ 2	16.0	27.0	6.5
6/29	8.5	15.0	11.5				
6/30	9.5	15.5	11.5				
7/ 1	9.5	15.0	11.5				
7/ 2	9.5	29.0	11.0				
7/ 3	10.0	24.0	7.0				

Table 2. Average lake depth measurements, Wood River sonar site, 1975-1979.

YEAR	DEPTH (ft.)	RANGE
1975	1.21	1.96 - (-) .78
1976	1.87	3.50 - 0.80
1977	4.99	-
1978	2.68	3.20 - 1.20
1979	3.06	4.78 - 1.08

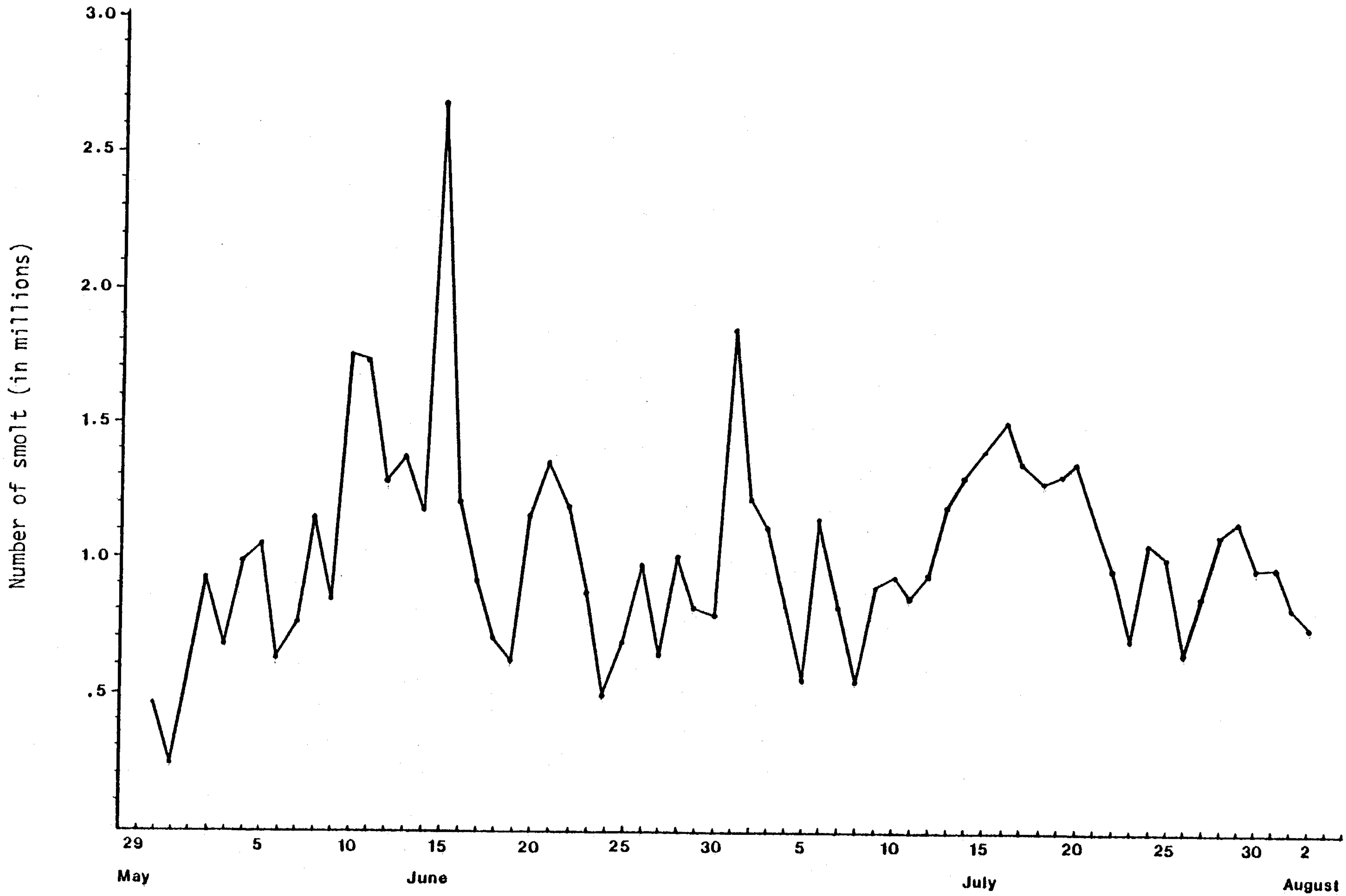

Figure 1. Estimated daily total outmigration of sockeye salmon smolt, Wood River, 1979.

Table 3. Estimated smolt outmigration by age class and sample period, Wood River, 1979.

Sample Period	Age I		Age II		Total
	No.	%	No.	%	
May 30 - June 3	2,350,385	83	481,404	17	2,831,790
June 4 - 8	3,903,024	86	635,376	14	4,538,400
June 9 - 13	6,256,418	90	695,158	10	6,951,575
June 14 - 18	5,878,308	88	801,587	12	6,679,895
June 19 - 23	4,464,415	86	726,765	14	5,191,180
June 24 - 28	3,479,753	92	302,587	8	3,782,340
June 29 - July 3	5,214,519	90	579,391	10	5,793,910
July 4 - 8	3,632,555	94	231,865	6	3,864,420
July 9 - 13	4,670,375	97	144,445	3	4,814,820
July 14 - 18	6,581,566	97	203,554	3	6,785,120
July 19 - 23	5,435,400	100	0	0	5,435,400
July 24 - 28	4,426,744	95	232,987	5	4,659,730
July 29 - Aug 2	4,544,720	98	92,749	2	4,637,470
Total	60,838,182	92.2	5,127,868	7.8	65,966,050

Table 4. Sample sizes, mean lengths (mm), and variances for Age I and Age II sockeye salmon smolt, Wood River, 1979.

	Age I			Age II		
Sample Period	n	$\bar{x}$	s^2	n	$\bar{x}$	s^2
May 30 - June 3	211	84.2	12.5	44	95.8	22.5
June 4 - 8	258	83.3	16.7	42	96.2	55.2
June 9 - 13	270	83.5	29.9	30	96.0	81.9
June 14 - 18	234	83.7	27.6	33	100.0	169.4
June 19 - 23	205	83.6	36.9	33	99.2	134.9
June 24 - 28	217	86.5	36.7	20	103.3	64.9
June 29 - July 3	73	89.1	56.9	9	107.1	71.2
July 4 - 8	204	90.3	47.5	14	106.2	72.5
July 9 - 13	146	92.9	31.7	4	100.0	114.5
July 14 - 18	93	95.5	34.0	3	106.3	57.6
July 19 - 23	20	96.5	27.6	0	-	-
July 24 - 28	228	95.2	23.8	12	93.7	47.2
July 29 - Aug 2	250	97.4	24.0	5	103.2	54.2
May 30 - August 11	2,409	89.7 1/		249	99.8 1/	

1/ Mean length for the entire season was derived by weighting each sample period's mean length by the total outmigration estimate for that period (Table 3).

Table 5. Mean length of sockeye salmon smolt by year and age class, Wood River, 1951-1979. 1/

Year of Seaward Migration	Age I Percent	Age I Mean Length in mm	Age II Percent	Age II Mean Length in mm
1951	80.0	91.0	20.0	-
52	99.0	87.0	1.0	-
53	95.3	86.0	4.7	103.0
54	95.8	87.0	4.2	107.0
55	98.0	85.0	2.0	102.0
56	78.4	82.0	21.6	95.0
1957	80.7	77.0	19.3	93.0
58	65.0	82.0	35.0	102.0
59	93.5	87.9	6.5	105.0
60	99.4	88.0	0.6	114.0
61	93.0	81.7	7.0	102.1
1962	86.0	80.1	14.0	97.6
63	84.3	82.6	15.7	102.1
64	98.8	83.7	1.2	104.2
65	92.0	85.5	8.0	106.1
66	94.3	77.1	5.7	101.2
1967-74 2/	-	-	-	-
1975	(86.0) 3/	82.5	(14.0) 3/	97.9
76	95.5	83.5	4.5	94.9
77	82.9	70.5	17.1	98.1
78	84.7	79.4	15.3	89.7
79	92.2	89.7	7.8	99.8
1951-79 Average	89.3	83.3	10.7	91.2
1951-66 Average	89.6	84.0	10.4	102.5
1975-79 Average	88.3	81.1	11.7	96.1

1/ 1951-74 Data Source: ADF&G Bristol Bay Annual Management Report, 1974. Age and length weighted by catch for a given sample period.
2/ Program not in operation or data not tabulated.
3/ Percentage not weighted by catch by period.

Table 6. Mean weight by sample period for Age I and Age II sockeye salmon smolt, Wood River, 1979.

Sample Period	Age I			Age II		
	n	y	s^2	n	y	s^2
May 30-June 3	149	5.2	.48	32	7.6	1.09
June 4- 8	258	5.4	.83	42	8.0	4.26
June 9-13	142	5.6	1.29	14	8.6	4.66
June 14-18	54	5.6	.81	8	9.0	20.91
June 19-23	39	5.7	.76	8	8.8	5.11
June 24-28	40	6.8	1.88	5	9.7	2.03
June 29-July 3	40	7.6	3.39	3	12.9	1.89
July 4- 8	38	7.9	4.34	4	11.05	7.25
July 9-13	49	8.7	3.12	1	-	-
July 14-18	30	10.1	2.29	2	12.5	-
July 19-23	-	(9.8)	-	-	-	-
July 24-28	50	9.3	1.65	1	9.1	-
July 29-Aug. 2	64	9.9	1.80	1	12.3	-

Table 7. Sample sizes and estimated infection by the cestode *Triaenophorus crassus* of Age I and II sockeye salmon smolt by sample period, Wood River, 1979.

Sample Period	Age I n	Age I % T.C.	Age II n	Age II % T.C.
May 30-June 3	211	27.0	44	68.2
June 4- 8	258	27.1	42	66.7
June 9-13	270	14.1	30	16.7
June 14-18	234	21.8	33	33.3
June 19-23	205	13.7	33	36.4
June 24-28	217	11.1	20	5.0
June 29-July 3	73	12.3	9	22.2
July 4- 8	204	7.4	14	7.1
July 9-13	146	2.7	4	0
July 14-18	93	2.2	3	0
July 19-23	20	0	0	0
July 24-28	228	0	12	0
July 29-Aug. 2	250	.4	5	20.0
May 30-Aug. 2		10.0 1/		30.8 1/

1/ The overall percentage of smolt infected by the parasite *T. crassus* was derived by weighting the percentage of infection in each sample period by the total expanded counts for that period (Table 3). Infection was only determined by gross external observations.

DISCUSSION AND RECOMMENDATIONS

Marine Survival Estimates

A summary of smolt outmigration estimates by age class for the years 1975-1979 is given in Table 8. These data are shown as they relate to brood year escapements in Table 9. After the 1979 season, adequate data were available to calculate marine survival from two brood year escapements. A total of 2.907 million 4_2 and 1.957 million 5_2 sockeye salmon returned from the 1974 escapement to the Wood River system. The 1974 escapement produced an estimated total of 113.950 million Age I and II smolt. Since sockeye salmon from the Wood River Lake system are virtually 100% 4 and 5-year-old fish, it may be assumed that 4.864 million fish were produced from the 1974 brood year. Marine survival was thus calculated to be 4.27%. Similar calculations for the 1973 brood year escapement indicated a 4.29% marine survival.

False Counts from Aquatic Debris

Since the sonar unit is a "biomass" counter, there was an intrinsic problem in that anything resembling smolt, including aquatic macrophytes, that passed over the transducers was also counted. During most of June there was little plant growth in the lake outlet, but during July the growth became increasingly thick, broke loose, and floated downstream, passing over the sonar arrays where it was counted as smolt.

The problem was compounded by tide reversals in the river, where high water and the change in current direction loosened plants and debris otherwise unaffected by normal flow. This resulted in a period of low counts during current reversals with an immediate series of high counts following the reversal. Visual checks, however, indicated that the high counts following a reversal could be attributed to debris in most cases. As plant growth increased and water levels dropped during the summer, the problem of false counts from aquatic debris became progressively worse. As river depth decreased, smaller high tides produced reversals with the same effect as a larger high tide.

It now appears that few, if any, smolt emigrate during the tide reversals. Sonar counts during these periods are few and occur in a random sequence (usually one or two count bursts) which was a more typical debris pattern. Interpolating across these hours using counts before and after the reversal would produce erroneously high estimates during the reversal. Counts of zero were therefore recorded during these periods in question.

It is not known what percentage of the total counts were "false counts" caused by aquatic debris, but for this reason, it was thought to be fairly significant during the last 2 weeks of counting. The percentage of "false counts" is also highly variable between seasons. Factors such as water level, tidal influence, water temperature, and incident radiation would all contribute to the debris problem in varying degrees.

A comparison of the dates when 90% of the smolt had passed the outlet may provide indirect evidence that the sonar is counting mostly debris in late July and August. Eggers and Rogers (1978) provide a summary of smolt timing in the Wood River system from 1951 to 1966 in Table 10. This data was obtained from

TABLE 8. Summary of smolt outmigration by year and age class, Wood River, 1975-1979, in millions of smolt.1/

Year of Outmigration	Age I	Age II	Total
1975	27.95	5.90	33.85
1976	101.40	4.80	106.20
1977	60.75	12.55	73.30
1978	46.60	8.40	55.00
1979	60.84	5.13	65.97

1/ Totally expanded sonar counts, derived by expansion factor of (5) smolt per count.

TABLE 9. Summary of smolt outmigration by brood year escapements, by age class, in millions of smolt and smolt production per spawner, Wood River, 1972-1977.

Brood Year	Escapement	Age I	Age II	Total	Smolt Production Per Spawner
1972	0.43	-	5.90	-	-
1973	0.33	27.95	4.80	32.75	99.24
1974	1.71	101.40	12.55	113.95	66.64
1975	1.27	60.75	8.40	69.15	54.45
1976	0.82	46.60	5.13	51.73	63.09
1977	0.56	60.84	-	-	-

Table 10. Summary of smolt migration timing for the Wood River system; dates on which 10, 50 and 90 percent of smolts migrated past Lake Aleknagik outlet, 1951 - 1979. 1/

Year	10%	50%	90%
1951	6/ 7	6/23	7/11
1952	6/12	6/25	7/18
1953	6/ 3	6/17	6/23
1954	6/ 2	6/10	6/15
1955	6/26	7/10	7/15
1956	6/16	7/ 6	7/12
1957	6/11	6/24	6/26
1958	6/ 9	6/15	7/ 1
1959	6/ 6	6/18	6/25
1960	6/ 2	6/18	7/10
1961	6/ 5	6/15	7/ 2
1962	6/13	6/21	7/ 5
1963	6/ 9	6/16	7/ 2
1964	6/21	6/30	7/ 5
1965	6/18	7/ 1	7/11
1966	6/17	6/26	7/ 8
Average	6/11	6/23	7/ 4
1967	-	-	-
1968	-	-	-
1969	-	-	-
1970	-	-	-
1971	-	-	-
1972	-	-	-
1973	-	-	-
1974	-	-	-
1975 2/	6/14	7/ 2	7/13
1976	6/20	7/14	7/29
1977 3/	6/13	6/26	6/27
1978 3/	6/ 8	7/ 5	7/28
1979	6/ 7	7/ 1	7/26
Average	6/12	7/ 3	7/25

1/ Source: Eggers, D.M. and Rogers, D.E. (1978).
2/ Iniation of sonar sampling program. Data in prior years was obtained from a fyke net index program.
3/ Extrapolated from total expanded counts by five-day period.

the old fyke net index program, while similar data for 1975-1979 was obtained from sonar sampling. The average date when 90% of the smolt outmigration had occurred was 4 July when indexed by fyke net, and 25 July when counted by sonar. This suggests that either a significant shift in the run timing had occurred or the sonar counter was counting aquatic debris as smolt. Methods to eliminate or reduce this source of error are presently being studied.

Water Level and Smolt Distribution

In 1975 when the sonar program was initiated, only two arrays were used. Results of the 1975 studies indicated that smolt distribution at the sonar site was not random (Krasnowski 1976). The inshore array (Array I), located 15.2 m from the north bank, consistently enumerated more smolt than the offshore array (Array III) located 33.5 m from shore. A side-scanning sonar unit used in conjunction with the two arrays could not be used due to the severe tidal fluctuations. It did indicate, however, that few smolt occurred in the southern third of the river channel in 1975. Later studies have shown, however, that this distribution pattern was not the same each year.

Two additional arrays were added to the sonar system in 1976 to better estimate smolt distribution across the river. Arrays I and II were placed in the same position as in 1975. Arrays III and IV were positioned 48.8 m and 61.0 m, respectively from the north bank (Krasnowski 1976). That year the accumulated sonar counts by array resembled the distribution pattern of 1975, i.e., more counts were recorded by Array I than by Array II. Newcome (1978, p. 27), however, reported that the smolt "distributed themselves more evenly over the four sonar arrays in 1977 than in 1976, but the majority of the total adjusted (for river velocity only) counts were still recorded by Array I."

Smolt distribution by array was not reported in 1978, but a definite shift in the distribution pattern was observed in 1979. The accumulated raw sonar counts by array are presented in Figure 2, while Figure 3 shows the total number of expanded sonar counts by array, after the various velocity factors have been applied and after expansions for the entire width of the river. Figures 2 and 3 show the same distribution pattern with one exception; Array IV has a higher percentage of counts than Array II in Figure 3. This was caused by the large expansion factor assigned to Array IV.

Although the distance from Array IV to the south bank was large, this portion of the river channel is also quite shallow and subject to severe water level fluctuations. The smolt, therefore, may not consistently use this part of the channel, especially during the latter weeks of the summer. Assigning an expansion factor based only on distance between arrays assumed that the smolt were evenly distributed across the river channel. That assumption was not correct. The Array IV expansion factor, therefore, was reduced from the initial 8.80 to 5.75 which changed the final outmigration estimate by nearly 10 million smolt. Thus, any error associated with the expansion factors has a direct and considerable effect on the accuracy of the final estimate.

In 1979 the sonar arrays were positioned on the river bottom with respect to positioning recorded in previous years. A review of these positions and the percentage of counts recorded by each array indicated that these positions may not yield the most accurate counts. A summary of smolt distribution by array, by year is given in Table 11.

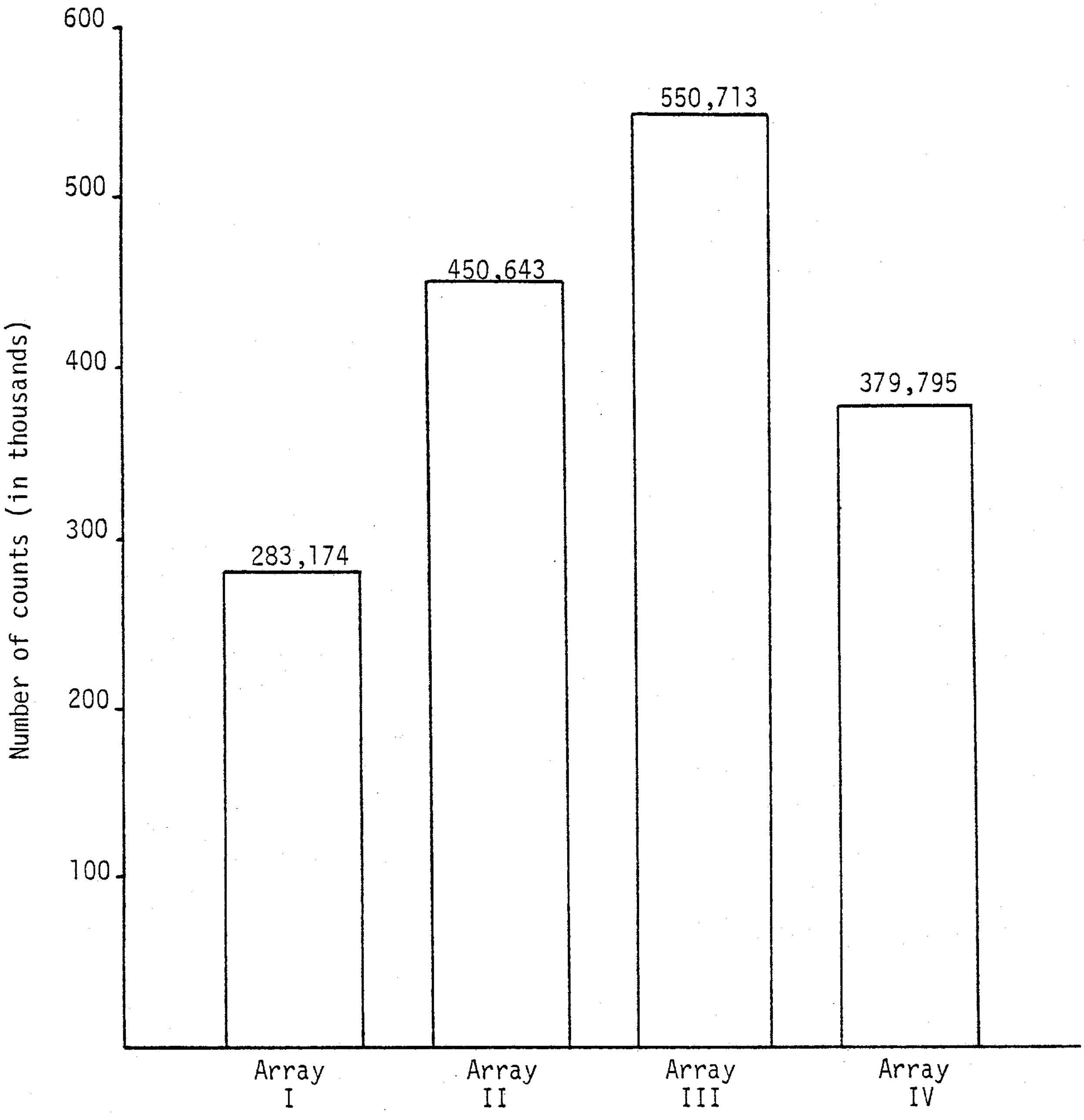

Figure 2. Number of accumulated sonar counts (before interpolation and expansion) by array, Wood River, 1979 1/.

1/ Raw counts were not adjusted for river velocity.

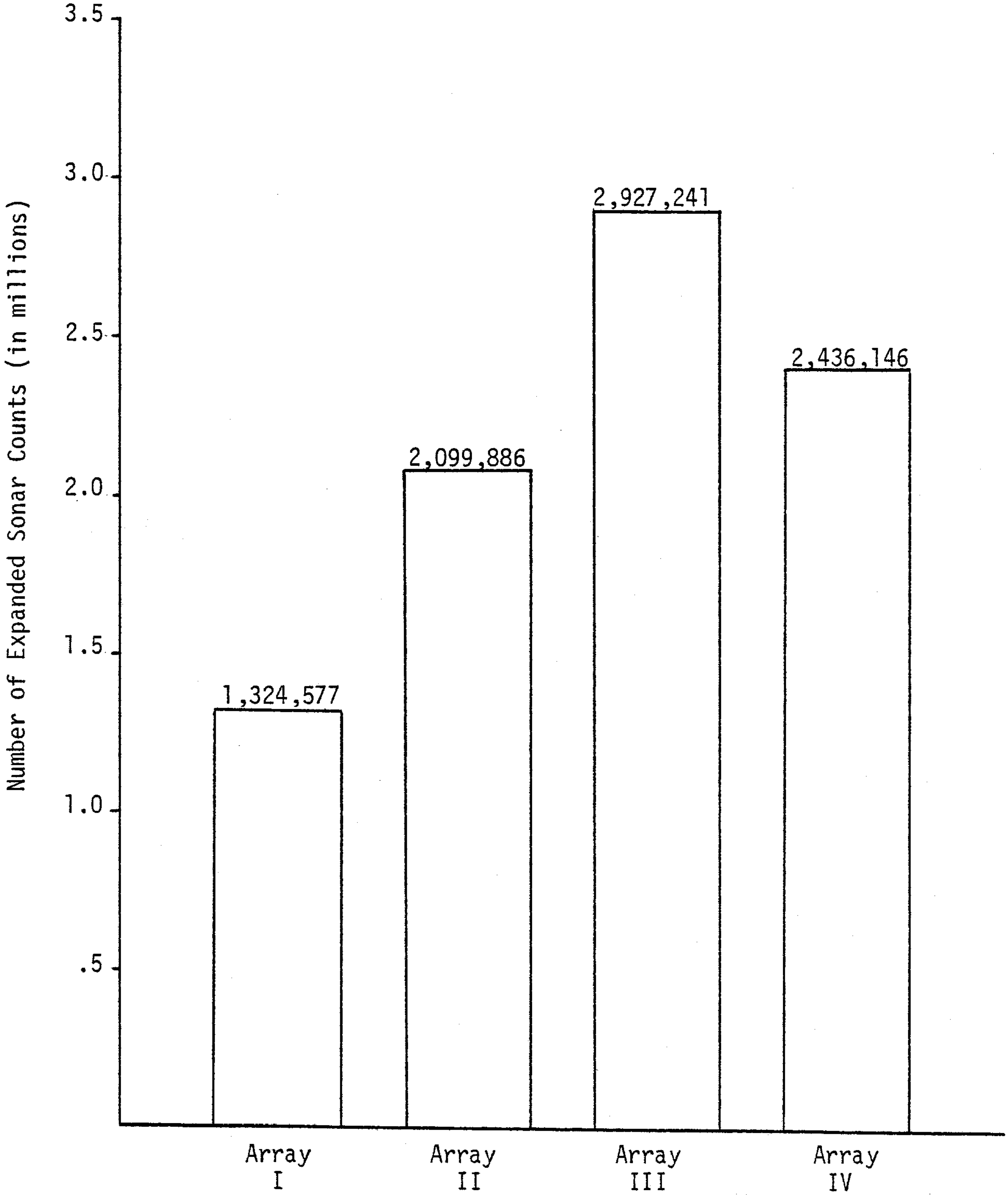

Figure 3. Number of accumulated expanded counts by array, Wood River, 1979 1/.

1/ Counts were corrected for river velocity and expanded for distance between arrays and shore, but do not reflect interpolation for hours not counted.

Table 11. Smolt distribution by array and year.

Year	Percentage of Total Counts			
	Array I	Array II	Array III	Array IV
1975 1/	68.6	31.4	-	-
1976	49.0	30.2	11.7	9.1
1977	36.0	24.4	20.8	18.8
1978	-	-	-	-
1979	17.0	27.1	33.1	22.8

1/ Only two arrays were used in 1975.

The changes in distribution patterns may be linked to water levels in the lake and river. Water levels in 1975 and 1976 were quite low relative to those in 1977 and 1979 when higher percentages of smolt were counted by offshore arrays (Table 2). Thus it may be possible to improve accuracy by distributing the arrays evenly across the river, although changing the array positions would sacrifice comparison of annual data. Further investigation is necessary before a change is warranted.

Adjustment of Sonar Counts for River Velocity

The entire length of the Wood River is subject to tidal influence, causing river velocity to fluctuate with the ebb and flood. River velocity was an important factor in determining actual numbers of smolt from sonar counts. The differences between actual river velocity and the velocity setting on the sonar counter caused the electronics to undercount or overcount in direct proportion to the ratio of the velocity setting on the electronics to the actual river velocity.

Since the sonar program was initiated in 1975, no less than four different methods have been employed to adjust the sonar counts for the actual river velocity. Krasnowski (1976) first developed a statistical velocity model (modified in 1977) from extensive measurements of lake and stream depth relative to current velocity measurements. Newcome (1978, p 25) attempted to do the same, but found that the river velocity data "were so variable that the model did not fit." Instead a correction factor was computed using the average velocity across the river per 5-day period. Clark and Robertson (in press) used the same technique for periods of no tidal influence (on velocity) but extrapolated sonar counts during tide influenced time periods from non-tidally influenced counts. Treatment of the 1979 data was similar, but still different in that correction factors were calculated for tide influenced counts as well. Improved accuracy of the count adjustment by this latest technique, however, required excessive amounts of time measuring river velocity with a Gurley meter.

These various techniques for correcting the sonar counts to actual river velocity have been not only difficult and time consuming to conduct, but have also added variability to the actual outmigration estimates. Therefore a flowmeter with a remote digital readout has been purchased for the 1980 season to simplify and standardize the treatment of sonar data. The meter will be installed in a permanent location in the river immediately behind the index array. This will allow technicians to simultaneously monitor river velocity in conjunction with the sonar counter. As changes in river velocity occur, the technician can quickly and easily change the velocity setting on the counter which will electronically "recalibrate" itself.

Beach Seining for AWL Samples

The standard technique for collecting smolt samples for this program has been beach seining at the outlet of Lake Aleknagik. Catch per unit of effort (CPUE) was recorded daily and at least 60 smolt were sampled for age-weight-length analysis. These data were used in conjunction with daily sonar counts to estimate timing and age composition of the smolt outmigration. Krasnowski (1976) found a linear relationship when he compared beach seine CPUE and total daily sonar counts, and used this relationship to estimate smolt outmigration during periods when the sonar counter was inoperative.

Beach seining at the lake outlet, however, has been questioned because smolt caught in the lake may not, in fact, be outmigrants. Also previous reports indicated that it became increasingly difficult to catch smolt by beach seine in the mid to latter part of the season. This trend was also observed in 1979, which required that smolt samples be collected by fyke net for the remainder of the season.

These changes in sampling techniques during the season have raised several questions concerning bias, gear selectivity, and reliability of age composition estimates. Some investigators claim that fyke nets are selective for smaller (Age I) fish. Others claim that beach seines do not capture a heterogeneous sample. Either case would lead to a biased sample and unreliable age composition estimates. Burgner (1962, p 258) reported that "sampling within the lake system by means of beach seines, lake traps, and fyke nets failed to furnish any evidence of an abundance of larger or older fingerlings not represented in the samples taken by fyke net at the outlet of the lake system. However, beach seine sampling in the lakes did show repeatedly that length-frequency composition varies greatly from one school to the next." Burgner's (1962, p 260) direct comparison of the two gear types indicated that "The fyke net samples were composed of portions of a greater number of schools, hence tended more toward the average size composition of all schools passing, and thus showed less variability in size composition between samples."

These findings support the idea of using a fyke net as the single means of collecting smolt samples. In addition, calibration of the sonar counter could be accomplished in conjunction with the collection of AWL samples.

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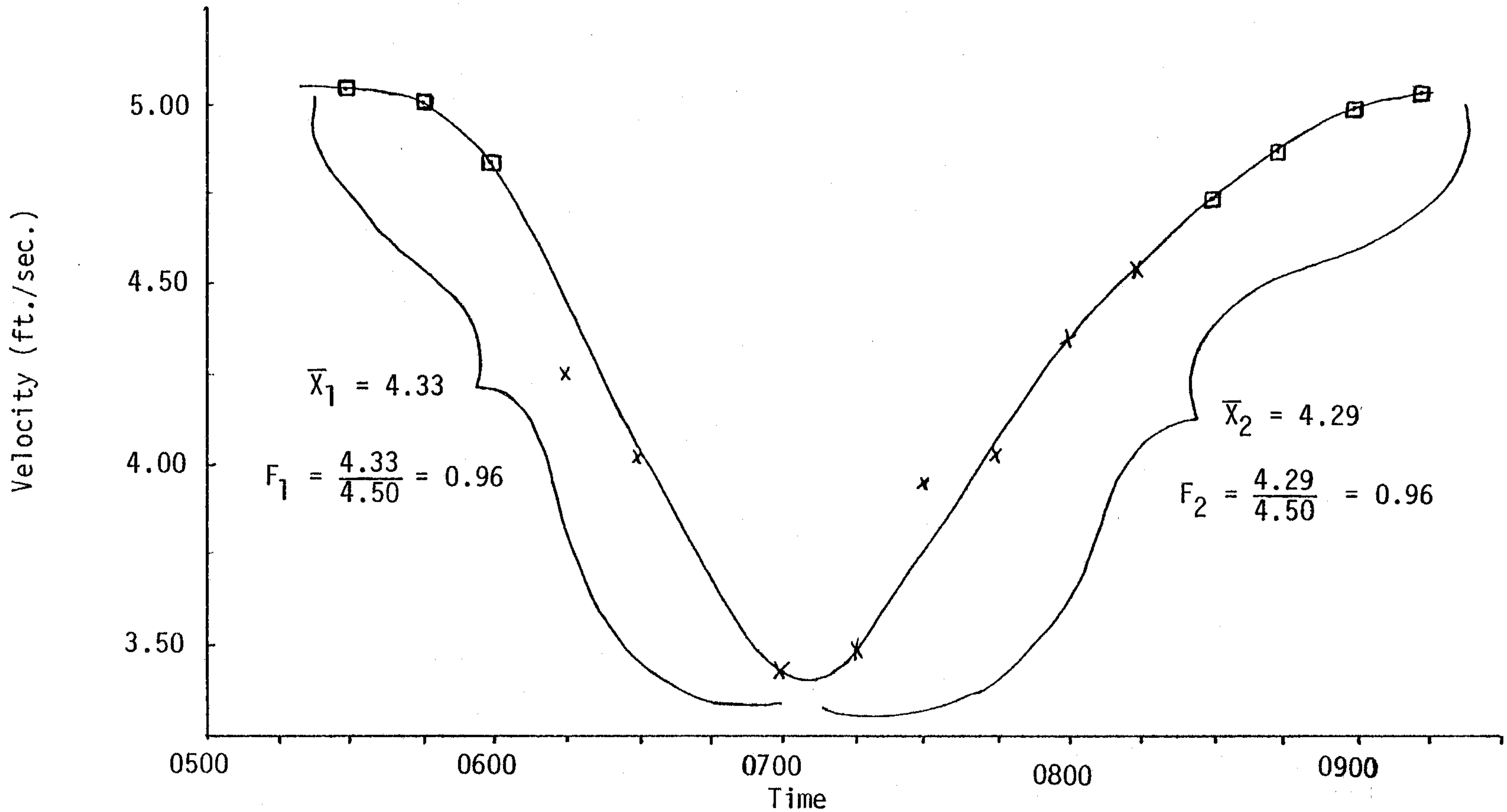
Appendix 1. Derivation of Tidal Velocity Factors (F_1 & F_2) used to adjust sonar counts during hours when river velocity is influenced by the high-high tide. New factors were computed for each five-day sample period.



$\overline{X}_1$ = Mean velocity during first half of the period of tidal influence on this date (6/13/79 - Sample period 3).

$\overline{X}_2$ = Mean velocity during second half of the period of influence.

F_1 = Computed tidal velocity factor for first half of period; $F_1 = \overline{X}_1$/velocity setting on smolt counter (4.5 fps).

F_2 = Computed tidal velocity factor for second half of period; $F_2 = \overline{X}_2$/velocity setting on smolt counter (4.5 fps).

x = Observed values measured with Gurley meter.

□ = Extrapolated values.

APPENDIX 2

Positions of the sonar arrays on the river bottom and derivation of the expansion factors used to obtain expanded counts.

The sonar equipment used in this program only counts a portion of the total number of smolt emigrating from the lake. This is because the four sonar arrays only sonify the river channel directly above them. Smolt passage in those sections of the channel not monitored by sonar must be estimated.

After the sonar arrays have been deployed their actual positions are measured in relation to the north and south bank. Each of the four arrays sonify an 11 foot section of the river. If the actual distances between the arrays are converted to 11-foot intervals, they can be standardized by the length of a single sonar array, with each 11-foot interval made equal to one (1).

Standardized lengths allow estimation of smolt passage for those portions of the river channel not monitored by sonar, using counts from the arrays on either side. Sonar counts from a given array are then multiplied by a constant factor associated with that particular array to yield estimated total expanded counts (ETEC).

The ETEC may be described by the following equation:

$$ETEC = \sum_{i=1}^{5} A_i + \sum_{i=1}^{4} X_i$$

Where

$A_1 = 5.68\ (X_1)\ (1/2)$

APPENDIX 2 (continued) .

$$A_2 = 2.09 \left(\frac{X_1 + X_2}{2}\right)$$

$$A_3 = 4.91 \left(\frac{X_2 + X_3}{2}\right)$$

$$A_4 = 3.00 \left(\frac{X_3 + X_4}{2}\right)$$

$$A_5 = 12.59\ (X_4)\ (1/2)$$

and

X_1 = velocity adjusted sonar counts from Array I

X_2 = velocity adjusted sonar counts from Array II

X_3 = velocity adjusted sonar counts from Array III

X_4 = velocity adjusted sonar counts from Array IV

By reducing the constants in the equation into terms of X variables the ETEC may be defined as:

$$ETEC = 4.88\ (X_1) + 4.50\ (X_2) + 4.96\ (X_3) + 8.80\ (X_4)$$

Note that the constant (8.80) in the above equation was reduced in the post season analysis. See "Water level and Smolt Distribution" in the discussion section of this report.

1979 SNAKE RIVER SOCKEYE SALMON SMOLT STUDIES

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INTRODUCTION

Lake Nunavaugaluk was chosen as the site for a sockeye salmon (Oncorhynchus nerka) fry production facility to supplement severely depressed natural production. Preliminary studies on Lake Nunavaugaluk were initiated in 1974 to estimate the number of sockeye salmon juveniles that the lake was capable of supporting. While these studies identified the location and extent of shallow water rearing areas important for early fry survival, no estimate was made of how many fry the lake could support (Jaenicke, Mattson, and Hoffman 1978). The number and age of sockeye salmon smolts migrating from the lake was determined to evaluate freshwater survival and production of sockeye salmon juveniles. Unfortunately, estimates of the total number of smolts leaving the lake were not considered to be reliable, since fyke net sampling could not be initiated until after the lake was ice-free. It was hypothesized that 50% of the total migration had occurred prior to this time (Thomason and Jaenicke 1979).

Studies described in this paper are a continuation of efforts to provide accurate estimates of smolt migration in Snake River. During 1979 the objectives were: (1) to determine whether large numbers of smolt leave the lake prior to or during the ice breakup, (2) to estimate the total number of smolt leaving the lake after ice breakup, (3) to estimate age and size composition of smolt leaving the lake, and (4) to conduct site surveys for placement of acoustic smolt counters.

METHODS AND MATERIALS

During ice breakup smolt sampling was conducted at two sites near the outlet of Lake Nunavaugaluk (Figure 1). Outlet width was about 1000 m and water depth ranged from 1.5 m (site B) to 3.7 m (site A). After ice breakup smolt sampling was conducted within Snake River, about 100 m below the outlet. River width was about 45 m, depth ranged from 0.3-0.9 m, and current speed varied from 2.9-4.9 fps. This site was the same used in all previous Lake Nunavaugaluk smolt studies (Thomason and Jaenicke 1979).

During ice breakup, attempts were made to capture smolts using sinking, variable mesh size (3.8, 3.2, 2.5, 1.9, and 1.3 cm square mesh) multifilament gill nets. One gill net was fished continuously at site B from 1445 h on 4 May, until 0730 h on 6 May. Another gill net was fished continuously at site A from 1445 h on 4 May, until 0730 h on 5 May. All Arctic char (Salvelinus alpinus) captured were examined to determine whether they had been feeding upon sockeye salmon

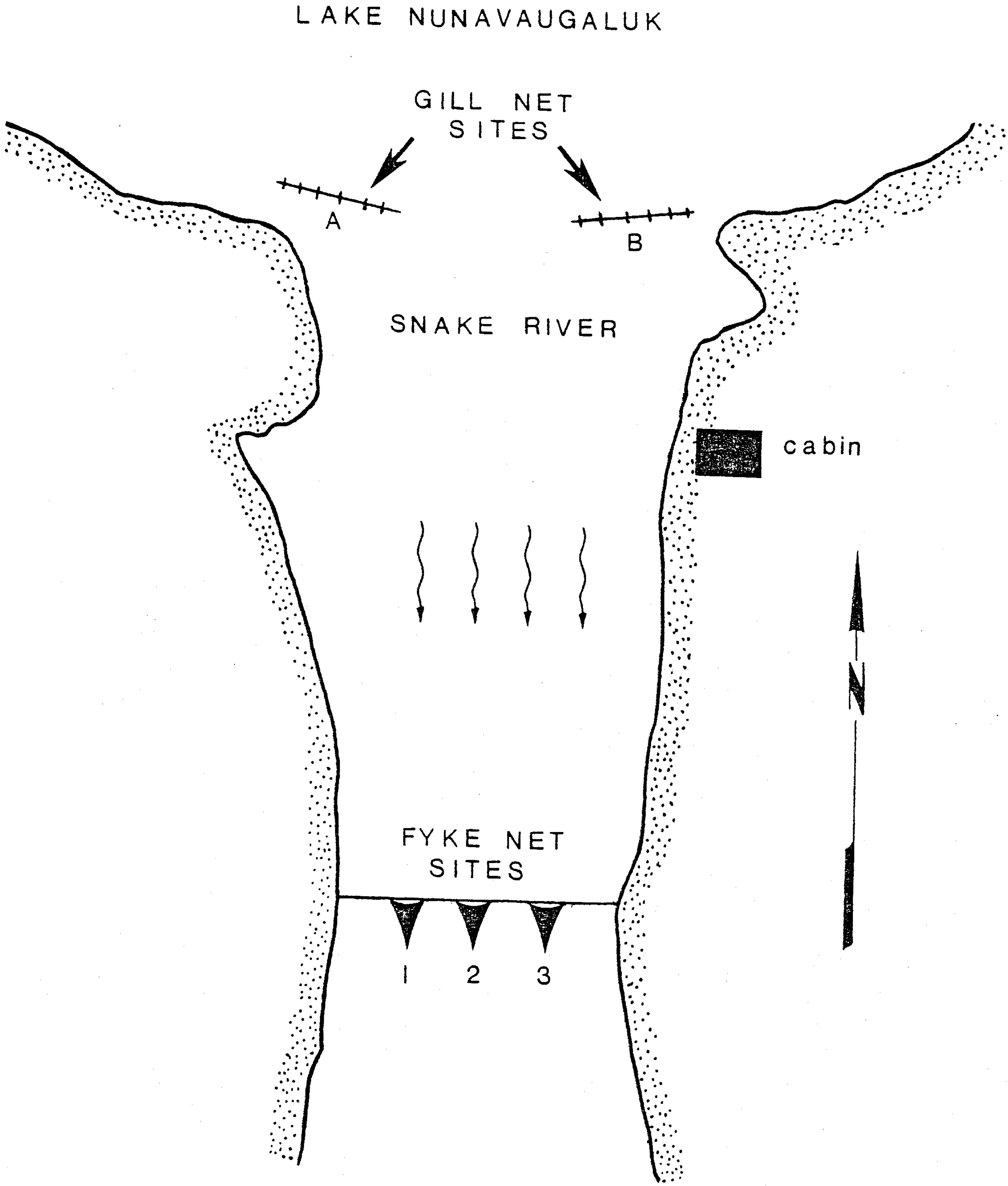

Figure 1. Area where Lake Nunavaugaluk drains into Snake River showing location of gill net and fyke net sampling sites for sockeye salmon smolts.

smolt. Gill net sampling was ended on 6 May because of ice floating at the outlet. Because of other project commitments for available personnel, smolt sampling was suspended until 16 May when the outlet and lake were ice free, and fyke nets were used to capture smolts.

Fyke net sampling was conducted from 16 May until 16 July using nets fitted with a floating live box (Thomason and Jaenicke 1979). Between 17 May and 5 July each sampling data consisted of three 1-hour periods (2300-2400, 2400-0100, and 0100-0200 h) and one 21-hour period (0200-2300 h). Since spatial distribution of smolts across the width of the river was not known, three locations were fished at the sampling site: one in mid-river and one near each river bank (Figure 1). A single location was fished during each period of a sampling day. The actual sampling schedule was determined prior to the field season by randomly assigning one of six combinations of location and period to each sampling day (Table 1). The fyke net was fished for 6 minutes at the assigned location during each of the 1-hour sampling periods. The net was fished continuously at the assigned location during the 21-hour sampling period. One 6-minute sampling period was missed on 11 June. Four 21-hour sampling periods (17, 19, 20, and 21 May) were not fished continuously due to accumulation of debris within the net. Between 17 and 25 May smolt migration during 0200-0300 h was estimated from a 6-minute fishing period since migration was too heavy to allow continuous fishing. On 16 May and after 5 July a fyke net was fished continuously at site 3. Catches made between 17 May and 5 July were used to estimate actual number of migrating smolt. Catches made before and after these dates were used only as migration indices. No sampling was done on 4 July.

Upon completion of each fyke net sampling period all smolt were removed from the live box, transported to shore in buckets, counted, and placed in a holding pen. Toward the end of each sampling day a random sample of 20 smolts was taken from the pen, anesthetized with tricaine methanesulfonate, measured for fork length, weighed (after blotting dry), and used for scale smears. On days when the total catch was less than 20 smolts, all smolts in the pen were sampled. All smolts were returned to Snake River, below the fyke net fishing site, prior to the start of each new sampling day.

Total smolt migration from 17 May until 5 July was estimated using the following formula:

$$T = 1/w \left(60/p \sum_{i=1}^{3} \sum_{j=1}^{d} n_{ij} + \sum_{j=1}^{d} n_{4j}\right), \text{ where}$$

T = total number of smolts leaving lake during sampling season,

w = proportion of total river width covered by fyke net = 0.049,

p = number of minutes fished during an hourly sampling period = 6,

d = number of days in sampling season = 48, and

n_{ij} = number of smolts captured on the j^{th} day during the i^{th} sampling period.

Table 1. Combinations of daily fyke net fishing locations and sampling times which were randomly assigned to sampling days during sockeye salmon smolt migration studies at Snake River, Alaska, 17 May to 6 July 1979.

Combination Number	Location 1	Location 2	Location 3	Time (hr)
1	X			2300-2400
		X		2400-0100
			X	0100-0200
	X			0200-2300
2		X		2300-2400
	X			2400-0100
			X	0100-0200
	X			0200-2300
3			X	2300-2400
		X		2400-0100
	X			0100-0200
		X		0200-2300
4	X			2300-2400
			X	2400-0100
		X		0100-0200
		X		0200-2300
5		X		2300-2400
			X	2400-0100
	X			0100-0200
			X	0200-2300
6			X	2300-2400
	X			2400-0100
		X		0100-0200
			X	0200-2300

The 95% confidence interval for the total smolt migration estimate was calculated by first computing a variance estimate for total smolt migration:

$$V(T) = d^2(1/w)^2 \left[[60/p]^2 \ (v[\bar{n}_1] + v[\bar{n}_2] + v[\bar{n}_3]) + v[\bar{n}_4] \right],$$

where:

$V(T)$ = variance estimate for total smolt migration, and

$V[\bar{n}_i]$ = variance estimate for mean smolt catch during the i^{th} period;

then using this estimate in the following formula:

$$95\%\ CI = T \pm t_{.05\ [d-1]} \sqrt{V(T)},$$ where:

$t_{.05\ [d-1]}$ = Student's value of t at the .05 level for [d-1] degrees of freedom

Data from 11 June, when a 6-minute sampling period was missed, was omitted from above calculations.

Smolt scales were mounted on glass microscope slides in the field and later viewed under a microfiche reader. Scale patterns were interpreted using criteria developed by Thomason (1979) for Snake River sockeye salmon smolts. To estimate age composition, mean length, and mean weight of the total smolt migration, the sampling season was divided into six periods of 8 days duration. Age composition by period was estimated from scale samples. These values were then multiplied by the total smolt migration estimates for corresponding periods to obtain the estimated number of each age class present by period. A seasonal total for each age class was obtained by adding all 8-day period totals. Mean length and weight for age class by period were calculated in a similar manner, and weighted.

On 11 and 25 October, surveys were conducted from the head of Snake River to about 3 km downstream to determine whether suitable sites were available for placement of an acoustic smolt counter. Requirements for an acceptable site were: (1) river depths between 1.5 m and 4.0 m; (2) river section free of entrained air; (3) water velocity between 1.0 and 10.0 fps; and (4) a river area in which smolt tend to school when migrating seaward (since biomass, rather than individual smolts, is counted by the unit). The following measurements were taken at potential sites: river width, river depth at 3 m intervals across the river, and water velocity (at mid-channel and 3 m from each shore). All measurements were made from a 5.5 m aluminum skiff which was tied to a rope stretched across the river. Depth was measured with a sounding line and lead during the first survey and a calibrated wooden pole during the second survey. Water velocity was measured with a Teledyne Gurley meter. Both surveys were conducted during low tide stage within Nushagak Bay. Since it was not known whether potential sites were affected by tide stage, a third survey was planned during high tide stage. Weather and ice conditions caused cancellation of this survey.

RESULTS

Climatological and Hydrological Observations

Daily water temperatures recorded from Snake River near the outlet of Lake Nunavaugaluk are presented in Table 2. Maximum and minimum seasonal water temperatures were 14° C and 4° C, respectively. All temperatures were recorded between 2300 and 0200 h.

Outmigration Estimate

No sockeye salmon smolts were caught in gill nets during 4-6 May when large amounts of lake ice were still drifting down Snake River. Five Arctic char and one ninespine stickleback (Pungitius pungitius) were caught in gill nets at this time. No sockeye smolt remains were found in any char stomach.

Sockeye salmon smolts were migrating from Lake Nunavaugaluk when fyke net sampling was attempted on 16 May. A total of 2,534 smolts was caught in a fyke net fished continuously at site 3 from 2300 h, 16 May, until 0830 h, 17 May. No lake ice was drifting down Snake River at this time and the south end of Lake Nunavaugaluk was ice-free. Fyke net sampling to estimate the total number of smolts migrating seaward, therefore, began 17 May.

An estimated total of 1,280,571 sockeye salmon smolts (95% CI: 918,505; 1,642,637) migrated seaward between 17 May and 6 July (Table 3). Nearly 87% of the smolts migrated between 17 May and 2 June (Figure 2). Approximately 80% of the total smolt migration occurred between 2400-0200 h, the darkest hours of the night (Table 4). Water temperature during peak smolt migration ranged from 4-5° C. Most smolts had migrated by the time water temperatures rose past 6° C (28 June). Less than 1% of the estimated smolt migration occurred between 27 June and 6 July. Index sampling between 6 July and 16 July yielded a total of 80 smolts.

Age-Weight-Length

Ninety-two percent of the total estimated migration consisted of Age I smolt. Peak migration of Age II smolts occurred earlier than peak migration of Age I smolts (84% total Age II smolts migrated by 25 May; 87% total Age I smolts migrated by 2 June). No Age II smolts were captured after 27 June (Table 5).

Mean length and weight of both Age I and II smolts decreased as the season progressed until mid to late June when they started to increase again (Table 6). The seasonal mean length and weight of Age I smolts were 101 mm and 9.0 g, respectively. The seasonal mean length and weight of Age II smolts were 131 mm and 19.5 g, respectively. These were the highest mean lengths and weights of smolts ever reported for Snake River (Table 7).

Smolt production per spawning adult was 127 Age I smolts and 8 Age II smolts (based upon escapements of 9,304 adults in 1977 and 12,728 adults in 1976, respectively). These figures represent minimum production estimates, since the smolt outmigration estimate did not encompass the entire outmigration period.

Table 2. Surface water temperatures recorded from Snake River, near Lake Nunavaugaluk outlet, during fyke net sampling for sockeye salmon smolts in 1979.

Date	Temp. (°C)	Date	Temp. (°C)	Date	Temp. (°C)
May 16/17	4.5	June 6/7	6.5	June 27/28	*
17/18	4.5	7/8	7.0	28/29	9.0
18/19	4.5	8/9	6.5	29/30	7.0
19/20	4.5	9/10	*1/	30/July 1	6.0
20/21	4.0	10/11	5.0	1/2	8.0
21/22	4.5	11/12	6.0	2/3	9.0
22/23	4.5	12/13	5.5	3/4	9.0
23/24	4.5	13/14	5.5	4/5	*
24/25	4.5	14/15	5.5	5/6	9.0
25/26	4.7	15/16	6.0	6/7	*
26/27	*	16/17	5.5	7/8	*
27/28	5.0	17/18	5.0	8/9	*
28/29	4.5	18/19	5.0	9/10	14.0
29/30	4.5	19/20	5.0	10/11	*
30/31	4.5	20/21	5.0	11/12	*
31/June 1	5.0	21/22	5.5	12/13	14.0
1/2	4.5	22/23	6.0	13/14	*
2/3	5.5	23/24	5.5	14/15	14.0
3/4	4.0	24/25	5.0	15/16	11.0
4/5	5.0	25/26	*	16/17	11.0
5/6	*	26/27	5.5		

*1/ Denotes missing data.

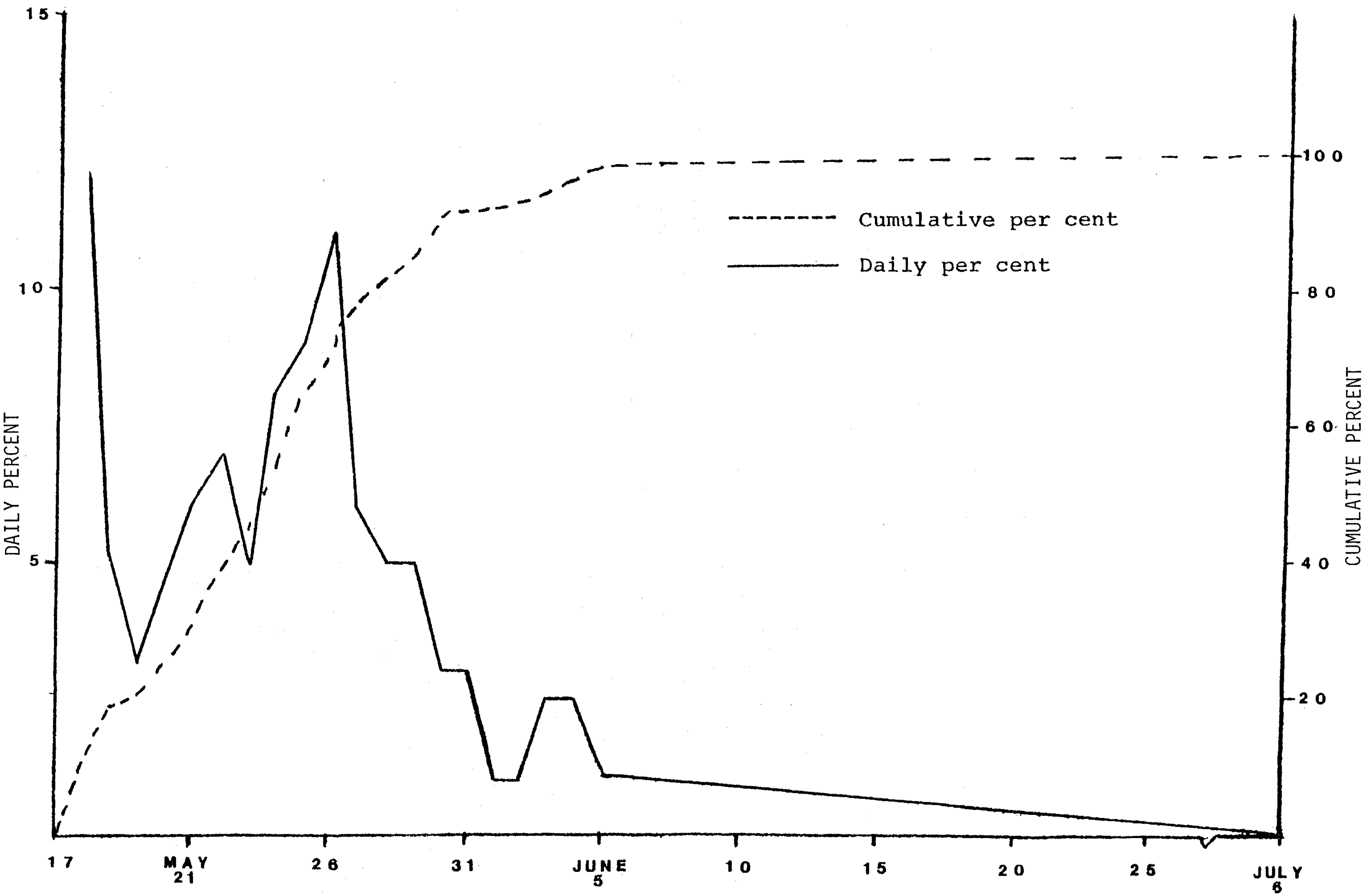

Figure 2. Daily and cumulative percent of total sockeye salmon smolts migrating from Lake Nunavaugaluk between 17 May and 6 July 1979.

Table 3. Sockeye salmon smolt migration estimates grouped by eight day time periods and age class, Snake River, Alaska, 1979.

Date		Number Age I	Number Age II	Total Number
May 17/25		504,504	82,129	586,733
May 25/June 2		522,060	10,654	532,714
June 2/10		93,377	2,888	96,265
June 10/19		28,721	1,197	29,918
June 19/27		23,478	726	24,204
June 27/July 6		10,837	0	10,837
	Totals	1,182,977	97,594	1,280,571

Table 4. Fyke net catches of sockeye salmon smolts, Snake River, Alaska, 1979.

Date	CN 1/	Catch per time period 2/ 2300-2400	2400-0100	0100-0200	0200-2300	Daily total
May 17/18	1	0	20	9,360	746	10,126
18/19	2	10	120	6,560	472	7,162
19/20	5	0	390	90	42	522
20/21	5	0	0	340	11	351
21/22	6	280	1,120	1,160	467	3,027
22/23	5	120	1,390	2,380	2,049	5,939
23/24	4	120	530	210	127	987
24/25	2	80	250	250	51	631
Total		610	3,820	20,350	3,965	28,745
May 25/26	5	530	4,900	2,090	3,703	11,223
26/27	3	60	100	1,510	233	1,903
27/28	5	0	1,630	1,150	508	3,288
28/29	1	60	1,680	1,330	511	3,581
29/30	2	220	70	600	258	1,148
30/31	3	590	1,600	950	368	3,508
31/June 1	5	40	270	330	57	697
1/2	6	10	640	90	15	755
Total		1,510	10,890	8,050	5,653	26,103
June 2/3	5	0	10	270	7	287
3/4	1	0	190	550	143	883
4/5	6	220	1,150	310	43	1,723
5/6	4	0	80	310	54	444

-Continued-

Table 4. Fyke net catches of sockeye salmon smolts, Snake River, Alaska, 1979 (continued).

Date	CN 1/	Catch per time period 2/ 2300-2400	2400-0100	0100-0200	0200-2300	Daily total
7/8	6	20	230	150	27	427
8/9	3	0	50	730	21	801
9/10	5	0	50	20	3	73
Total		240	1,810	2,360	307	4,717
June 10/11	4	0	10	0	1	11
12/13	3	0	40	40	11	91
13/14	2	0	480	260	36	776
14/15	6	0	90	10	16	116
15/16	3	0	230	30	6	266
16/17	2	0	80	0	10	90
17/17	2	0	90	0	15	105
18/19	5	0	0	10	1	11
Total		0	1,020	350	96	1,466
June 19/20	2	0	0	30	8	38
20/21	2	0	120	150	30	300
21/22	5	0	60	260	72	392
22/23	2	10	70	120	25	225
23/24	6	20	90	0	7	117
24/25	6	0	60	20	6	86
25/26	2	0	10	10	3	23
26/27	2	0	0	0	5	5
Total		30	410	590	156	1,186

-Continued-

Table 4. Fyke net catches of sockeye salmon smolts, Snake River, Alaska, 1979 (continued).

Date	CN 1/	Catch per time period 2/ 2300-2400	2400-0100	0100-0200	0200-0300	Daily total
June 27/28	6	10	20	10	9	49
28/29	4	0	50	20	1	71
29/30	2	0	80	80	14	174
30/July 1	3	0	30	30	1	61
1/ 2	2	10	40	0	3	53
2/ 3	3	0	10	30	0	40
3/ 4	4	10	20	0	0	30
5/ 6	2	0	30	20	3	53
Total		30	280	190	31	531

1/ Combination number: specific fyke net locations fished, per Table 1.

2/ Catches shown are hourly estimates based upon 6 minutes of sampling per hour.

Table 5. Age of sockeye salmon smolts as determined from scale samples grouped by 8-day time periods from Snake River, Alaska, 1979.

Date	Sample size	Percent Age I	Percent Age II
May 17/25	160	86	14
May 25/June 2	160	98	2
June 2/10	147	97	3
June 10/19	121	96	4
June 19/27	112	97	3
June 27/July 6	72	100	0
Total	772		

Table 6. Mean length, mean weight, variance, and sample size for sockeye salmon smolts grouped by 8-day time periods and age class from Snake River, Alaska, 1979.

	Age I					Age II				
Date	Mean fork length (mm)	Variance	Mean weight (g)	Variance	Sample size	Mean fork length (mm)	Variance	Mean weight (g)	Variance	Sample size
May 17/25	103	85.4	10.1	2.82	138	133	39.7	20.6	6.56	22
May 25/June 2	100	57.8	8.4	3.09	157	122	116.7	16.3	20.34	3
June 2/10	95	43.1	7.1	1.92	143	98	16.2	7.9	1.41	4
June 10/19	92	28.0	6.6	1.37	116	98	44.6	8.2	2.73	5
June 19/27	93	21.7	7.2	1.52	109	100	6.88	8.6	0.08	3
June 27/July 6	95	13.4	7.5	1.01	72	---	---	---	----	--
*Weighted means	101		9.0			131		19.5		

*Based upon actual number of Age I and II smolts migrating during each 8-day period.

Table 7. Mean lengths and weights of sockeye salmon smolts from Snake River, Alaska, 1973-1979.

Year 1/	Age I		Age II	
	Fork length (mm)	Weight (g)	Fork length (mm)	Weight (g)
1973	92	6.7	122	11.8
1974	92	7.3	---	----
1975	94	8.0	105	10.1
1976	91	6.3	---	----
1977	96	8.0	---	----
1978	93	6.8	104	9.4
1979	101	9.0	131	19.5

1/ Data for 1973-1978 from Thomason and Jaenicke (1979).

Sonar Site Investigations

Two sites potencially suitable for acoustic smolt counter operation were found about 3 km downstream from the lake outlet. On 11 October, both sites had marginally acceptable water depths for operating unmodified smolt counters, which required depths of at least 1.5 m. On 25 October, only site II had acceptable depths. Water discharge at the lake outlet was similar on 11 October (1404 cfs) to the May and June averages (1,466 and 1,065 cfs, respectively) when smolts could be migrating (U.S. Geological Survey, unpublished data). Mean water velocity at both sites during both surveys was 3.9 fps. It may be possible to locate the sonar site closer to the head of Snake River as acoustic counters can be modified to point downriver at an angle of 20° allowing operation in water depths of only 0.9 m (Al Menin, Bendix Corporation, personal communication).

DISCUSSION

Seasonal and diel timing of sockeye salmon smolt migration from Lake Nunavaugaluk during 1979 was similar to patterns reported for this system in past years (Thomason and Jaenicke 1979). However it did not appear that smolts migrated prior to lake ice breakup or while ice was still drifting down Snake River, as was postulated by Thomason and Jaenicke (1979). Smolts probably leave the lake as soon as the south end is ice-free. Once migration begins it is rapid and of short duration; a typical pattern for smolt migration in single lake systems (Hartman, Heard, and Drucker 1967). This makes it imperative to have personnel available to remain on site during lake ice breakup so that sampling can begin as soon as conditions allow.

Lake Nunavaugaluk sockeye salmon smolts appear to be the largest produced by any system within Nushagak Bay (Thomason and Jaenicke 1979). Large smolt size, predominance of Age I smolts and high smolt production all indicate that conditions within Lake Nunavaugaluk have been favorable for rearing juveniles resulting from adult escapements of about 10,000 sockeye salmon. However optimum carrying capacity of the lake for sockeye salmon juveniles is not known. It will be important to continue to monitor size, age, and production of smolts migrating from the lake as efforts to increase adult escapement and introduce additional fry to the system from East Creek Hatchery continue. Large increases in the number of rearing sockeye salmon juveniles could result in decreased smolt size, increased lake residence time prior to smoltification, and lowered smolt production.

It was hoped that the present fyke net sampling scheme would provide a reasonable, unbiased estimate of total number of sockeye salmon smolts migrating seaward from Lake Nunavaugaluk. Sampling periods were stratified according to known temporal distribution of smolts to provide more precise information about the smolt population and to decrease the variability of the estimate. Sampling location was randomized since actual spatial distribution of smolt across the river width was unknown. However, smolt migration estimates derived from fyke net catches must still be viewed with caution. Fishing efficiency of the fyke nets used should be determined. Use of 6-minute fishing periods to estimate actual catches during a 1-hour fishing period must be evaluated early in the season when large numbers of smolts migrate and late in the season when few smolts migrate. Also methods used to calculate variance and confidence intervals of the total migration estimate should be re-examined to determine whether necessary statistical assumptions were satisfied. Use of acoustic smolt counters would solve some of the problems associated with fyke net sampling since a greater proportion of river width could be monitored during sampling periods, fewer smolts would be subjected to stress from capture in fyke nets and, if necessary, counters could be operated while ice was still present at the south end of the lake.

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